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Conservation and management of the Mediterranean coastal sand dunes in Israel

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Abstract. The aims of this study are to review the current situation of the Israeli Mediterranean coastal sand dunes, to examine the causes for this situation, and to propose options for future conservation and management of the protected dune areas based on ecological, environmental, landscape and recreational demands and interests. The coastal dunes of Israel are characterized by diverse plant communities, with 173 plant species occurring on sand (8.2 % of the total flora of Israel) including many endemic species (26 % of all endemic species in Israel). Most of the species are annuals. The importance of the coastal strip as a centre of floral and faunal speciation is also manifested in the existing sand-bound animals. However, many species are rare. This is mainly due to the extensive industrial and urban development along the coastal plain and the direct and indirect destruction of the remaining open dune areas by tourism, recreation and sand mining. Only ca. 17 % of the Israeli coastal dunes are still of good or reasonable ecological value, while < 5 % of this area has been designated as protected area. Management policies differ from place to place and depend on local objectives. These objectives derive mainly from the knowledge and data that exist for each location, and its statutory status. Since 1995 several projects, which aim to develop integrated management tools for nature conservation and recreation uses for all coastal sand dunes in Israel have been conducted. These projects are summarized in the present paper.

Keywords: Endemism, Rare species; Recreation; Sand mining; Tourism.

Introduction

The issue of open spaces is currently being discussed in various forums for development planning both in Israel and around the world. Israel's National Master Plan (NMP) for construction, development and absorption of new immigrants for the next 20 years (NMP 35) is seriously concerned with the issue of protected open spaces in several of the country's regions. The issue of open spaces is also discussed with reference to urban regions. The contribution of open spaces to urban landscape, to the quality of the environment and to the quality of life is without doubt (Sukopp et al. 1995).

Simply defined, open spaces are areas without construction. They can be divided into three main categories, according to the intensity of human interference: natural areas (for example, nature reserves), semi-natural areas (for example, planted forests and pasture lands), and artificial areas (for example, agricultural lands). Similarly, these three categories can also be found in urban areas: wastelands, planted forests and woodlands, and public gardens with lawns and exotic plants.

The significance of open spaces is expressed in a variety of ways, including ecological importance, environmental quality, economic values, social interaction and landscape aesthetics. A complex relationship exists between plants and animals in open spaces. Feedback system functions can reduce various air, water and soil pollutants. Open spaces are conducive for the development of recreation and ecotourism sites, and act as social meeting places. Their contribution to the exterior beauty of a region influences a person's enjoyment of an area from a psychological perspective. This affects a person's behaviour, particularly in the environment in which he/she spends most of his time (Sholowiz 1987).

Coastal areas in general are considered to be areas in which human impact and the level of development are among the highest (Drees 1997; Holdgate 1993; van der Meulen & Salman 1996). The aims of this study are to review the current situation of the Israeli Mediterranean coastal sand dunes, to examine the causes for this situation, and to propose options for future conservation and management of the protected dune areas based on ecological, environmental, landscape and recreational demands and interests.

Characteristics of coastal sand dunes

Israel's coastal sand dunes extend along a strip of 190 km. The width at the south end of the strip is 7 km; this tapers to 1 km in the north. The total area of the strip is ca. 580 km^2 (Fig. 1).

Most of the sand dune strip is within the Mediterranean biogeographical region. In this section, the mean annual rainfall varies from 300 mm in the south to 700 mm in the north. The most southern section of the coastal plain belongs to the Sharo-Arabian biogeographical region. The mean annual rainfall in this area (south of Ashkelon) is lower, varying from 200 mm to 300 mm. Characteristic habitats of the coastal plain are sand dunes, aeolianite ridges, the coastal cliff, red sandy loam soils (Rhodoxeralfs), salt marshes, and seasonal pools.

Uniqueness of coastal sand dunes

The strip of sand dunes along Israel's Mediterranean coast is continuously connected to the desert sand dunes of the Negev and northern Sinai. This connection provides a corridor for the northward distribution of desert (Sharo-Arabian) species. Although most of the coastal sand dunes are under Mediterranean climatic conditions, this distribution is possible because of the area's relatively harsh physical conditions. Instability of the sand, low soil moisture and nutrient availability transform these coastal sand dunes into a xeric habitat. Survival is relatively more difficult for plants and animals in this habitat than in others in the Mediterranean region.

The spatial geographical continuity between the coastal sand dunes and those of the Negev and northern Sinai and their isolation from other habitats in the Mediterranean region because of their harsh environment, have created special conditions that allowed Sharo-Arabian plants and animals to live alongside Mediterranean species as they adapted to the new conditions. In this way, the coastal sand dunes in Israel have become an active laboratory of evolution and natural selection, in which subspecies and new species endemic to the area were evolved. Two examples hereof are the psammophilous rodent *Gerbillus andersoni allenbyi*, a subspecies endemic to the northern coastal plain of Israel, and the psammophilic annual plant species *Senecio joppensis*, endemic to the coastal sand dunes region. The rodent developed from a desert species that distributed northward, and the plant is an adaptation of the Mediterranean *S. vernalis* that invaded the xeric habitat of the coastal sand dunes.

The unique habitat conditions in the coastal sand dunes also caused morphological and phenological changes in species that live there. These changes cause this population to differ from populations of the same species in other habitats. This phenomenon is defined as ecotypic differentiation; plants that represent this feature are called ecotypes. This differentiation is known in several species, including *Artemisia monosperma, Retama raetam*, *Echium angustifolium* and *Nigella arvensis*.

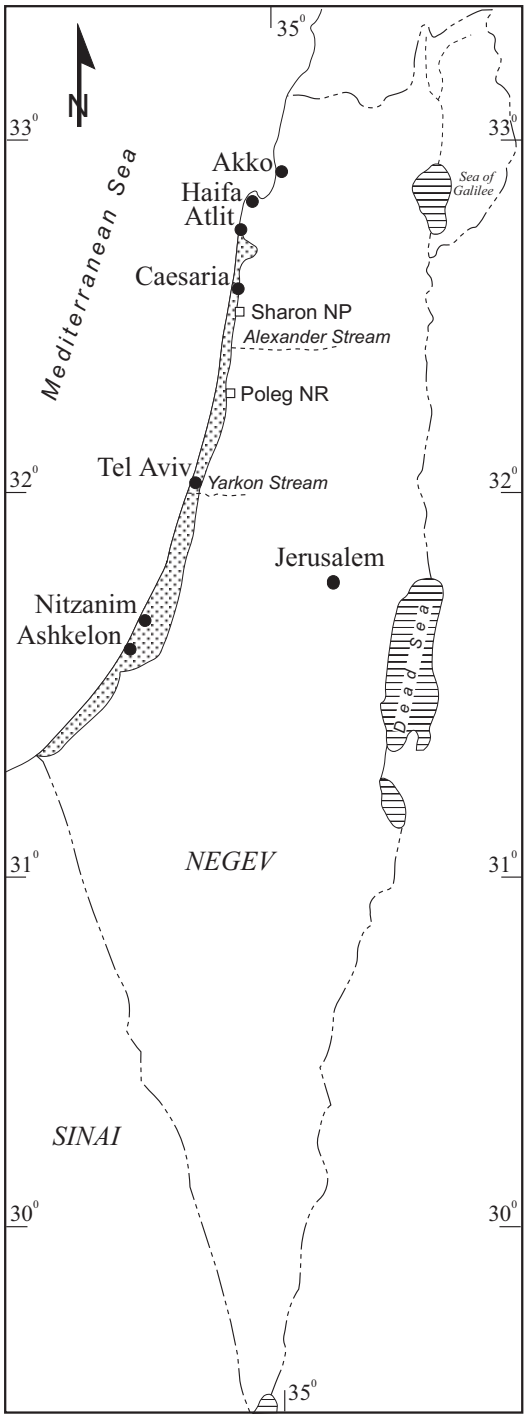

Fig. 1. The coastal plain of Israel.

Properties that demonstrate the differences between coastal ecotypes and inland ecotypes include, among other things, tendency to succulence, a manner of prostrate growth and late flowering (Waisel et al. 1975). The issue of plant and animal ecotypes in Israel has been minimally researched. It is therefore possible that many other species have coastal subspecies.

The coastal sand dune region is well known for the relative richness of endemic plants. 26 % of Israel's endemic species (31 species, most of them annuals) are concentrated in this region. This percentage is the highest rate of endemism in one habitat. Some of these species can also be found outside of Israel's borders, in the direction of Egypt and Lebanon. Most of the species are neo-endemic (young endemic species that were created during or at the end of the Pleistocene) (Shmida 1982).

Coastal sand dunes are also characterized by diverse species of psammophilic animals. These include the lizards *Trapelus savignii*, *Acanthodactylus scutellatus*, *Sphenops sepsoides* and the largest (ca. 160 cm) lizard in Israel *Varanus driseus*, the sand snake *Lytorhynchus diadem*, the rodents *Gerbillus pyramidum* and *Meriones sacramenti*, the only endemic mammal in Israel, and the sand hedgehog *Hemiechinus auritus aegyptius*. Most of the endemic species of the coastal sand dunes are desert species or phylogenetic derivations of Mediterranean species. The phylogenetic derivations of Mediterranean species have not been researched thoroughly, and the knowledge about them is scarce (Prof. A. Zahavi pers. comm.; Shmida 1982).

Rare plants and animals can also be found in the coastal plain. Some of these are in danger of extinction (Fragman et al. 1999). There are 140 plant species found in the central and the southern coastal plain that are considered to be in various degrees of rarity. Of these, 43 species are 'rare' (species that grow in 31 - 100 sites), 80 species are 'very rare' (species that grow in 4 - 30 sites), and 17 species are considered to be on the verge of extinction (data for 2000 received from the Israel Plant Information Center). This said, it is important to emphasize the small number of species from the sandy and sandy loam soil habitats that have actually become extinct: 3.9 % from the total extinct species in Israel. This is in spite of the extensive destruction of these habitats since the establishment of the State of Israel in 1948 (Naveh & Kutiel 1990). Although there has been a drastic reduction in the rare plant populations in these habitats since 1948, this has not led to extinction (Fragman et al. 1999). In total, 173 psammophilic plant species are known to grow in Israel's sand and sandy loam soil habitats (8.2 % of Israel's total flora species). There are 11 additional species typical of the coastal cliff (0.5 % of Israel's total flora species) (Fragman et al. 1999).

The coastal plain is characterized by a variety of landscape units (shifting, semi-shifting and stabilized sand dunes, sand plains, aeolianite ridges, depressions, seasonal water pools, and stream estuaries) and by a variety of calcareous soils (sand, regosol with an A-C soil profile, red sandy loam soils, alluvial grumosol, hydromorphic and para-rendzina). Characteristic plant communities typify each landscape unit (Kutiel 1998b; Kutiel et al. 1979/1980; Dan & Kutiel 1997).

Sandy habitats are more conducive to observation of pedological and successional changes over time than are other habitats. Such changes in soil include changes in structure, texture, colour, fertility and stability. In plants, they include changes in cover, height, composition, species richness and species diversity. In Israel for example, in the sand dunes of the northern coastal plain, 10 successional stages (pioneer to climax) have been discerned. Each stage was characterized by plant community type and soil properties (Kutiel et al. 1979/80; Danin & Yaalon 1982; Kutiel 1998a, b).

Furthermore, in the coastal plains there is also an abundance of prehistoric and historic sites such as Akko, Atlit, Caesarea and Ashkelon. Among other things, these sites contain evidence of climatic changes that have occurred in the area over the past 10 000 years (Netser 1994).

The coastal sand dune strip is divided into two ecological sub-units, north and south. The Yarkon River (that crosses Tel Aviv from the east to the west) demarcates the border between these two sub-units. The units differ from each other in degrees of aridity and, accordingly, in plant formation and composition. For example, the northern coastal plain contains plants such as carob trees (*Ceratonia siliqua*), lentisc shrubs (*Pistacia lentiscus*) and oak trees (*Quercus ithaburensis*) that are absent from the southern coastal plain. Based on maps and other documents, the fact that these shrubs and trees are dispersed throughout the region in patches is evidence of forest areas that covered the area in the past. Difference between the two sub-units is also evidenced in animal distribution. For example, the rodents *Gerbillus andersoni allenbyi* and *Meriones tristrami* are prevalent in the northern coastal plain and missing from the southern sand dunes.

Present conditions

The sand dune area has diminished since the establishment of the State of Israel. For example, in the northern coastal plain the sand dune area has been reduced by more than half since 1944 (Kutiel & Sharon 1996). Moreover, the shifting sand dunes are undergoing a process of gradual stabilization that is expressed in their morphological form and by their high percentage of shrub cover (> 80 %). A glance at the 1818 Jakotin map, the 1878 PEF (Palestinian Explorer Foundation) map, and British aerial photographs from 1944/1945 reveals that the northern coastal plain was characterized by longitudinally shifting sand dunes and sand fields. The maximum plant cover in the months December-

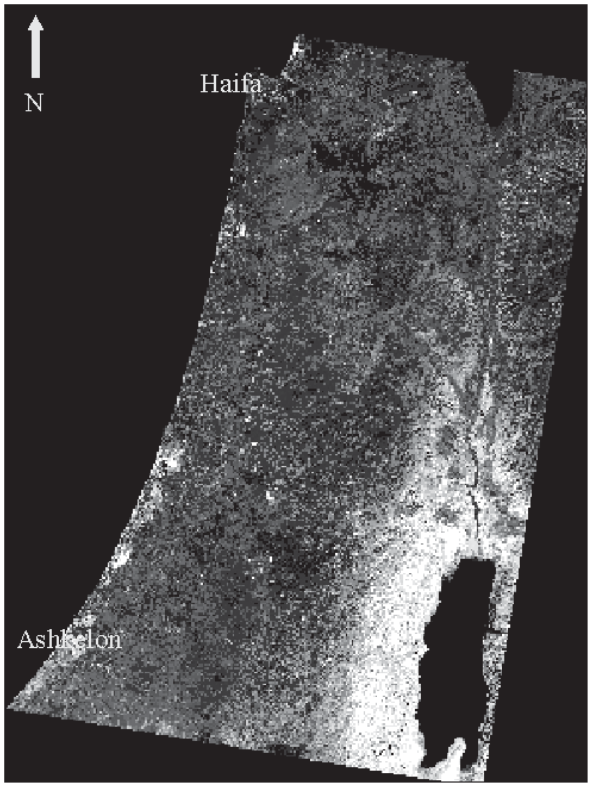

Fig. 2. Satellite image (Landsat TM) of Israel indicating the vegetation cover (in red) along the coastal plain (winter 1996; pixel size 30 m ¥ 30 m).

January 1944/1945 reached ca. 20% and was concentrated in areas of depressions (where the water table is high), along streams, in flood plains and in swamps (Kutiel & Sharon 1996). Barzilay et al. (1998) described a similar condition in the south coastal plain of Israel.

Regardless of the cause, the fact remains that today, the sand dunes are almost inactive and their perennial plant cover is very high (about 80 % in the north and 40 % in the south) (Fig. 2). The ecological significance is expressed by changes in the physical and biotic components that characterize shifting and semi-shifting coastal sand dunes (Kutiel et al. 2000a).

In Israel, nine habitats are defined as in danger of extinction (less than 2 % of the habitat area is conserved); of them, five are located in the coastal plain. They are sand dunes, shoreline (tidal range), red sand loam soils (these soils, which were formed out of dune sands during the glacier periods in the Pleistocene, have been intensively cultivated), salt marshes and seasonal water pools. Along the Mediterranean shore in Israel, there exist 20 coastal nature reserves (among which only 15 are statutory declared) and 16 national parks. These stretch along the shoreline for 42 km. Not all of these areas have a clear statutory status. Of the 42 km, 16 km are declared, 2 km are approved and 24 km are proposed nature reserves.

The total area of declared, approved and proposed nature reserves along the coastal plain is ca. 48 km^2; this is 8 % of the total area of coastal plain. Of the total nature reserve areas that are declared and proposed along the coastal plain, the sand dunes comprise ca. 66 %. Of them, 94 % are located in the southern part of the coastal plain. The average area of conservation in each of the declared nature reserves is less than 0.5 km^2.

Reasons for the present conditions

As noted previously, coastal areas are in general highly sensitive to development and human resource utilization (van der Meulen & Salman 1996; Holdgate 1993). This is also the situation in Israel (Golik 1997; Naveh & Kutiel 1990). In the following, some main reasons are given for landscape changes and damages to Israeli dunes.

As a result of massive immigration and a high rate of population growth (the highest among developed countries), the human population in Israel's coastal plain increased dramatically during the 20th century. It rose from less than 100 000 inhabitants in 1948 to more than 3.5 million today (Golik 1997). The population density at present in the central region of the country (which consist of the Tel Aviv Metropolitan) is 1064 inhibitants/km^2 (The Israeli Central Bureau of Statistics).

This intensive growth in population density along the coast has extracted multiple and continually increasing demands and development on the coastal zone. These are expressed in construction of living quarters (urbanization) and infra-construction of roads, industrial zones, power plants, oil and coal terminals, tourist and recreational sites, ports and boat anchorages and military sites. Military sites, industrial installations, power plants and ports and boat anchorages occupy more than 25 % (55 km) of the seashore. Cities occupy more than 20 % (44 km) of the seashore. The decrease in the sand dune areas along the coast has been simultaneously accompanied by direct and indirect environmental and ecological changes.

Most of the sand on the Israeli coast is not indigenous. Since the formation of the Nile Delta, waves and currents have driven sand from the Nile Delta eastward along the coast of Sinai to the Israeli coast. Construction of the Aswan Dam in the Nile, (the low one in 1902 and the high and main one in 1964) significantly reduced sand input into this system. Furthermore, massive amounts of sand have been mined from the Israeli coastal dunes since the beginning of this century (mainly since the establishment of the State of Israel in 1948) until the practice was stopped by law in 1964. This, and

the intensive construction of many coastal structures along the Israeli coastal plain, which entrapped high amounts of sand, has caused a significant reduction in the amount of sand supplied to the Israeli Mediterranean coast. It is estimated that more than 20 million m^3 of sand was removed from the tidal system during the second half of the 20th century. The removal of sand and the obstruction of the normal supply of sand, which is today less than 10 % of the amount before the construction of the high Aswan Dam, have caused the beach to narrow by more than 20 m (Golik 1997).

Some argue that the stabilization processes of sand dunes are due to global (Netser 1994) and local (Alpert & Mandel 1986) climate changes. According to Alpert & Mandel (1986), the surface wind speed in central-southern Israel has been significantly reduced since 1964. They suggested that this change indicates a meso-scale modification of climate, which is induced by agricultural development and settlement in the central to southern part of Israel in recent decades. Such land use modifications have caused a change in surface albedo (decrease) and surface roughness (increase). These, in turn, have increased the atmospheric instability conditions that has resulted in an increase in convective rains, and reduction in the temperature difference between land and sea that has resulted in a reduction of wind speed. According to Barzilay et al. (1998), the low wind speed measured today close to the sea is insufficient for significant sand transportation. They assert that the slow rate of transportation (1.9 m/yr) together with the postulated increased rainfall, permits the establishment of plants and the stabilization of sand dunes. However, there are others who argue that stabilization processes of sand dunes are due to changes in local land uses that have occurred over the course of years. Such changes include the transformation from agricultural cultivation, grazing and cutting (land use characteristics of the nomadic tribes that populated the area before 1948) to nature conservation and the full protection of sand dunes.

Until recently, the policy of the Nature Reserve and National Park Authority was characterized by strict prohibition of grazing and all human interference in areas under its supervision. According to some researchers, this prohibition caused the dominance of perennial plants and the stabilization of sand dunes (Barzilay et al. 1998). It is possible that dune stabilization and high shrub cover is a result of climatic and land use changes, as well as other direct and indirect anthropogenic impacts.

The dune areas of the coastal plain are among the preferred sites for tourism and recreation. This is because of their close proximity to both the sea and large urban centres. The development of recreation and tourism sites and uncontrolled recreational activities damage the fragile texture of various habitats of sand dunes (Kutiel et al. 1999, 2000b).

An example of this type of damage can be observed in the prominent recreational activity of off-road vehicle travel. This phenomenon is increasingly popular in Israel and around the world. Traffic in open spaces, particularly in those areas with high ecological sensitivity, disturbs soil, vegetation and wildlife (Kutiel et al. 1999, 2000b). The disturbance is both local and wide=spread. This is because of the high access of off-road vehicles to places that were previously considered isolated and inaccessible. This is demonstrated in the spontaneous increase of trails all over the open spaces in Israel, including the coastal area. The trail density in the Sharon National Park, for example, has reached 22 km/km^2 and in the area of the Sharon Coast National Park it has reached 40 km/km^2 (both parks are located in the northern part of the coastal plain). The annual increase in trails in this area over the last 10 years is ca. 3 km of trails per km^2 (Kutiel 1999). Pedestrian and vehicular traffic has caused damage to the soil and plants over 15 % of the total area of Sharon National Park (Kutiel et al. 1999). A similar situation exists in other mentioned sites.

Sandy habitats, especially stabilized and semi-stabilized sand dunes, are especially sensitive to vehicular traffic. This is because the upper soil layer (5 - 10 cm deep) is rich in litter and organic matter (A-C soil profile). The moment this layer is destroyed, the mineral soil of the dune is exposed and the transition from a state of stabilized sand dune to a state of shifting sand dune is swift. Both plant species richness and species diversity of stabilized sand dunes depend upon the upper soil layer (Kutiel et al. 1999, 2000b).

In Israel, conservation activities of open spaces with high ecological and landscape values began in 1964, with the legislation of the Nature Reserves and National Park Law. The main objective of nature reserves according to this law is to protect ecological and landscape values, while national parks serve mainly recreation purposes. The majority of the national parks in Israel are located in archeological and historical sites (e.g. Akko, Caesarea and Ashkelon). However, few national parks, such as the Sharon National Park, include nature reserves.

The main efforts over 20 years since the legislation of the Nature Reserves and National Park Law were directed towards the conservation of mountainous Mediterranean ecological systems (Kaplan 1993). Coastal plains were not high priority for conservation and as such, only areas located along the margins of human settlements were declared nature reserves. Due to this fact, the area of most of the 15 declared nature reserves is relatively small. It varies from between a few hectares to several hundred hectares. The biggest nature reserve

in the coastal plain at present is 50 ha. Most proposed nature reserves (reserve sites that have not yet been officially declared and currently exist in various stages of the planning process) are concentrated in the southern part of the coastal plain. These are larger than the declared nature reserves and are supposed to range between 287 to 900 ha. According to van der Meulen & Salman (1996), the optimum area for conservation of coastal sand dunes in the Mediterranean basin area must be between 500 and 1000 ha.

Until the mid-1980s, in the coastal plains as in all of Israel, conservation of protected areas meant complete protection. Grazing, prescribed burning and all other human interference were prohibited and prevented through a variety of measures. 20 years of this type of conservation has demonstrated the importance of controlled and dynamic management. Many researchers have noted that human interference in Mediterranean ecosystems is necessary to maintain high species diversity of plants and animals in natural and semi-natural open spaces (Kutiel 1993, 1997; Naveh & Whittaker 1979; Shmida 1985).

The lack of management tools and policies in sandy areas accelerated the stabilization of the sand dunes and the dominance of woody plants. This caused a reduction in the plant and animal populations characteristic of shifting and semi-shifting sand dunes (Kutiel 2000a).

Solutions for dune landscape changes and damages

The planners and designers of Israel's National Master Plan 35 recognized the importance of open spaces. In their assessment of Israel's open spaces, they included the strip of sand dunes along the coastal plain and various sections along the Mediterranean seashore as areas of coast to be conserved. This was done on the basis of several NMPs, including NMP 13 for coasts, NMP 8 for nature reserves and national parks, NMP 12 for tourism and NMP 22 for forestation. It was also based upon several Regional Master Plans (RMP), among them RMP 4 for southern region, RMP 21 for central region and RMP 6 for the coastal Carmel region. The principal question asked by the authorities responsible for the preservation of protected open spaces is: What management policy should be applied to those areas (if any), especially to the coastal sand dunes, in order to preserve the landscape, plants and animals that characterize those habitats? The authorities did not identify specific problems to be addressed, thus the ecologists are challenged by a definition of problems, appropriate research questions and methodologies, and the supply of convincing answers to the principal questions raised by the authorities.

Defined aim of management

Developing management policies for a specific area depend primarily upon the defined aims for that area. For example, if a specific area is defined as a protected area on the basis of one or more endemic species or, alternatively, on the basis of unique species that exist in the area, the management will be focused upon the aim of conservation of those organisms. The assumption is that protecting them assures protection of the whole ecosystem. The Alexander Stream National Park in the northern coastal plain (adjacent to the southern boarder of the Sharon National Park) serves as an example. After a preliminary survey to quantitatively assess the area's inventory, the management was targeted to protect and encourage the population growth of rare sand-living plants and animals. The population size (cover and number of specimens) of the psammophilous herbaceous plants and animals related to the respected associations in the sandy area under discussion was small. This may be brought about by the dune stabilization and the massive shrub cover that began with the establishment of Israel and which has persisted until present times (Kutiel 2000a). In order to realize this conservation aim, it was decided to completely remove aboveground woody vegetation. The assumption was that the new conditions in the bare area would encourage repopulation and increase the existing sand-living herbaceous annual species and the gerbil (*Gerbillus andersoni allenbyi*), which is considered endemic in the northern coastal plain. The gerbil's habitat in the area under discussion is currently occupied by the existing field mouse (*Mus musculus praetextus*).

The results of the research demonstrated that removal of perennial vegetation reduces the mouse population and encourages gerbil dominance. In addition, the annual plant cover rose significantly in the treated sites, when the species that characterize the sand, such as *Rumex pictus*, *Daucus glaber*, *Crepis aculeata*, *Brassica toumefortii*, *Cutandia philistaea* and *Corynephorus divaricatus* were dominant. This situation persisted for at least five years after the removal of the vegetation.

The practical conclusion that resulted from this work is that deliberate removal of dense woody vegetation can serve as a management tool for areas that are designated for the conservation of species diversity that characterize the region. Today, after five consecutive years of research, the removal of woody vegetation in a patchy form from the top of the stabilized sand dunes is part of the Nature Reserve and National Authority management in this area. However, when the aim is rehabilitation of habitats, management strategies must be adjusted. In this case *in situ* seeds and characteristic plants from the undisturbed areas should be dispersed in the

adjacent disturbed areas in order to accelerate the establishment and growth of these species. Projects that used this strategy were conducted in Sharon National Park and are currently being carried out in sand dunes and on the coastal cliff of the Poleg Nature Reserve.

Active interference in the ecosystem is not always necessary. Areas for which it is known that diverse landscape units, habitats, plants and animals are secure and there is no danger to the survival of rare or endemic species can serve as 'control' research sites.

The aim is not always identified and clear to the manager of an area. For this reason, protection is often carried out from a general desire 'to protect', rather than with a specifically defined protection aim. As mentioned above, sandy habitats are very small; therefore, the aims for protected habitats within these sites must be clearly defined. The aims must also be dynamic and changeable over time based on long-term observations and research results and conclusions (Fig. 3).

Surveys and research

The aims for protection of open spaces are derived from a variety of information sources. These include research, surveys, maps, aerial photographs, etc. that exist for given areas. In many cases, relevant information does not exist or is only partially existent; for example, data only on plants or sporadic data on all the organisms in an ecosystem.

In order to direct both long and short-term management policies, it is necessary to gather existing and new data on the inventory of a given area in a systematic manner. It is necessary to investigate the various ecological and environmental aspects of the gathered data. Relevant research questions may include the following:

- What is known about the area before it was disturbed (that is, before intensive agriculture and/or construction activities were carried out)?
- What are the changes that have occurred in the area since the disturbance?
- What is the ecological and environmental significance of the changes that occurred in the ecosystem?
- What are the species that currently populate the area?
- What is their degree of frequency?
- What are the dynamics of the populations?
- What is the minimum territory for each species?
- What are the relationships between the species?
- What is the rate of reproduction and distribution of each species? How is the ecological system affected by human interference (for example, grazing, burning, reforesting and recreation pressures)?
- What is the carrying capacity of the area?

The system for methods of data collection must be uniform for every habitat and acceptable by the authorities responsible for each area in a way that meaningful comparisons are possible between habitats and we learn both about and from each habitat.

There is a great deal of information about vascular plants in sandy and sandstone habitats. The variety of plant communities (Danin & Orshan 1999) and the location of endemic and rare plant species are known at the Israel Plant Information Center (see also Fragman et al. 1999). Information about animals in these habitats, however, is scarce and limited. In fact, information about reptiles and insects is extremely little. Surveys and research on these animals were collected in different periods and in various manners. The data are not systematic and, therefore, it cannot be compared nor can it lead to clear conclusions.

Sensitivity map

Sensitivity maps or maps of nature, landscape and heritage values divide a given area into sub-areas that have different sensitivities or values. Sensitivities/values are a weighted result between the existing inventory in every place in the area and the ecological importance of this inventory to the area size and to the area's degree of continuity. Sensitivity rises when the rarity of the elements in a specific area increases while the size of the area and the degree of continuity decreases.

Information derived from recent research and surveys of a given area is gathered into a database. This database is the source of information for the sensitivity map. The map's resolution increases as the number of

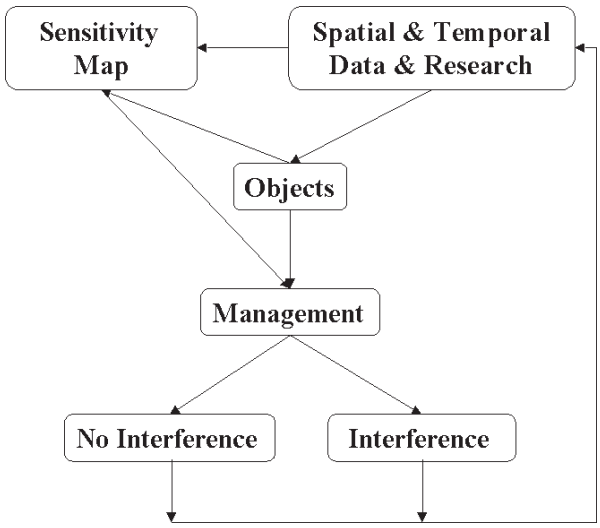

Fig. 3. The information and tools needed for the management decision maker.

systematic surveys and research on the area increases. Such a map can then be the basis for any management and development activities in a given area. The survey departments of the Society for the Protection of Nature prepares these maps on the basis of criteria that were developed by Gidilizon (1988). The criteria are divided into two main groups: ecological criteria such as cover, rarity, representation, spatial continuity, and scientific and educational values; and comparable criteria – the relative conservation degree of a habitat or a landscape unit as compared to the most conserved unit of the same type. The criteria are evaluated by experts from various scientific fields, and analysed by GIS methods. Such sensitivity maps have been prepared for several areas along the coastal plain of Israel.

Management

Management includes all means and activities that are planned and carried out for the preservation, recovery conservation, and restoration of nature, landscape and heritage values. Management must be based on aims that are defined for a specific area, according to that area's sensitivity map. Management must be based on an understanding of the total processes and their variability in time and place in the ecosystem of the given area.

Management policy may be expressed as non-interference and preservation of the present situation. One form of this management is the closure of damaged, high sensitivity areas to visitors. Recovery conservation of this sort has as its aim the return of the situation that existed before the disturbance. This was one of the strategies in the Poleg Stream Nature Reserve (north of Tel Aviv and south of Sharon National Park) and in the stabilized sand dunes of Sharon National Park. In these areas, reduction and recovery of trail systems were recommended (Kutiel et al. 1999).

Alternatively, management policy may be expressed by creating conditions to encourage anticipated future processes (biotic and abiotic). This was done in Alexander Stream National Park and Nitzanim Sands Park. In these instances, the aim was to restore bare sandy landscape so that the areas would resemble their condition 50 years earlier. The goal is to encourage the existence of sand-living plant and animal populations. The removal of undesired plants may be achieved with the help of herbivore animals and/or through removal by man. Each of these methods must be evaluated to determine ecological implications and costs.

As mentioned before, the area of many declared reserves is quite small. For this reason, land use adjacent to the reserve is likely to influence the reserve itself. Management must take this fact into account and be involved in land use both inside and outside the reserve boundaries.

In principle, there exists today a nationwide trend to combine agricultural areas in the total area of nature reserves and national parks with the aim of creating spatially continuous units (Ecological corridors). One benefit of this is the potential to allow the free distribution of plants and animals. Another benefit is the additional economical value (Ecotourism) to farmers of the cultivated areas (for example, landscape and migrating bird populations that stop in the cultivated areas). Clearly, this integration needs governmental support in the form of compensations and agricultural policies that are environment-friendly. Unfortunately, in the State of Israel, that is far from being a reality.

Surveys and research must be accompanied by public cooperation and involvement. Explaining a variety of issues to the public will reduce damage to coastal areas. It will also strengthen the public's perception of the value of the landscape. Public opinion is very important to achieve the aim of conservation and management of the sandy areas in the coastal plains that are, unfortunately, disappearing from the landscape.

In Europe, as in other parts of the world, management of coastal dunes was focused on dune stabilization, as bare dune landscapes and sandy ecosystems were considered of no value and interest. Likewise, shifting sand dunes had been a serious threat to various land uses, due to sand movement. This approach has lately changed, as a result of geomorphological and ecological studies that emphasized the importance of mobile sands as being an intrinsic part of dunes (Nordstrom & Lotstein 1989). However, sand stabilization in Israel was not a main management issue, as they stabilized naturally. On the contrary, vegetation was removed by cutting and grazing. Such interference maintained the bare dune landscapes and their ecological and geomorphical characteristics. Today, the coastal dune situation in Europe and in Israel is very similar: the dunes have been stabilized and the shifting sand dunes are in danger of extinction.

Extensive studies on coastal dune management were conducted in Holland (e.g. Veer & Kooijman 1997; ten Harkel & **v**an der Meulen 1996). These studies led to a new management approach in which above-ground vegetation cover plus organic horizon have been removed**,** in order to re-activate mobile dunes.

Stabilization of the coastal sand dunes by planting still is a common management tool practice in the Mediterranean countries as well as in many other parts of the world. In England, Ireland and The Netherlands grazing is the main tool to maintain high species diversity in the coastal dunes (McManus 1988; Doody 1985; Veer & Kooijman 1997; ten Harkel & van der Meulen 1996).

However, in Israel the main shrubs (*Artemisia monosperma* and *Retama raetam)* that dominate the coastal sand dunes are not palatable, thus grazing alone cannot be used as an efficient tool for biodiversity objectives.

The management of coastal sand dunes in Israel is focusing on keeping high landscape heterogeneity and restoration of the dynamic landscape along with the sand-living flora and fauna. Thus, the manager should understand the significance of landscape heterogeneity, and the ecological significance of shifting coastal dune reduction.

Big efforts are invested in re-introducing mobile sands, grazing and cutting sods for conservation of sand-living organisms and for reasons of stimulating natural processes, such as those that characterized the coastal dunes only 50 years ago.

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